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UPPER MISSOURI RIVER

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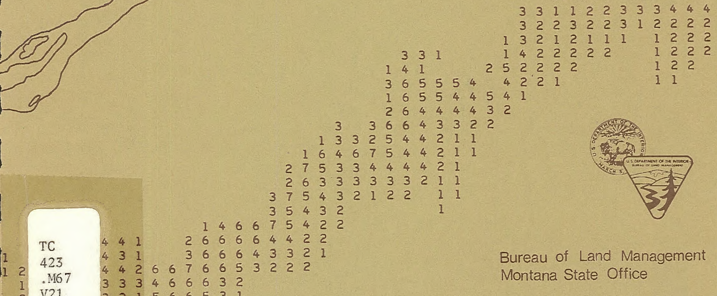
MAPPING SCENIC BOUNDARIES & VISUAL VULNERABILITY with VIEWIT



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FORWARD

The following study was undertaken by Tomm Van Dyke, during the summer of 1977. At that time, he was a graduate student in Landscape Architecture at Harvard University.

Donald Johnson, computer programmer, and Dwight Araki, landscape architect, were of technical and supervisory assistance.

This report is a documentation of how this study was conducted. It is not the only way nor the best way that the task could have been completed. However, for the time and resources available, this approach is the most effective way for the task to be completed.

INTRODUCTION

For the past 10,000 years, the Upper Missouri River has been carving a magnificent and unique landscape across northern Montana. Its present course is the result of the final Wisconsin glacial movement through this area. Due to the relative youth of this course, the walls rising along the banks of the River are impressive with their rugged, carved sandstone formations of outstanding scenic quality.

In their westward expedition, Lewis and Clark were the first explorers to document the scenic grandeur of the River. We can observe the same features noted in their journals, and also locate other historic places, such as the site where Chief Joseph encountered the calvary.

Recognizing the historic significance and unique qualities of this natural resource, Congress designated the Upper Missouri River a National Wild and Scenic River in October of 1976. This classification requires an overall management plan which provides a procedure to protect this natural resource. At the same time, the plan recognizes and plans for the needs and demands of people on this area.

One part of this management plan is the Visual Resource Management (VRM) of the River. Being a legislated Wild and Scenic River, we assume that the visual character of the Upper Missouri River is a unique and important natural resource. By mapping and analyzing the areas that can be seen from the River, a management plan can be worked out which preserves the existing natural, primative scenic quality along the River. This management plan will help to reduce the impacts of existing activities which can be seen from the River, such as farm structures and roads. It will also help to site future activities that must occur here, such as bridges, powerlines, or recreational buildings, to ensure minimum visual impacts on the scenic quality of the River.

In this report, we will use several terms which help explain the process we followed in order to lay the foundation for managing the River's scenic quality. The total area which can actually be seen from this 149 mile stretch of the River is called the viewshed of the River, somewhat similar to the idea of a watershed. This viewshed thus includes all the land which must be carefully managed to protect the scenic quality of the River.

Unusuel eroded sandstone formations resembling castles, parapets, and other encient structures border the river, which is generally wide and slow-moving. Outcroppings of dark intrusive rock thrust upward through this white sandstone, forming what appears to be huge manmade walls of rectanguler blocks. The opportunity to view the wildlife and unique geologic features combines with the slow wanderings of the river to provide a unique boating experience.

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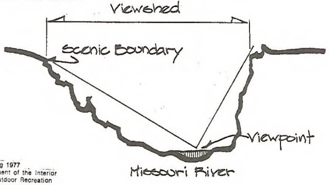

The edge of the viewshed farthest from the River is called the scenic boundary. This scenic boundary on each sice of the River is called the rim-to-rim boundary of the River. The Wild and Scenic Rivers Act requires us to locate and map this rim-to-rim boundary since it serves as the legal bounds for all lands which will be protected.

Included in this rim-to-rim boundary then are the River, its flood plain, and the slopes which rise to the horizon, cresting at the point where the plains begin. By locating this rim-to-rim boundary, lands can be identified for acquisition in order to create a scenic easement along the River. The scenic quality of the River can then be protected.

METHODS

Mapping the viewshed of the River and locating the rim-to-rim boundary is difficult to carryout by hand, entailing numerous float trips on the River with subsequent helicopter checks. The accuracy of this method is ensured only by a generalization of detail. In other words, it is tough to draw what you see in three dimensions onto a two dimensional map, so you have to ignore most detail and draw generalized boundaries.

Rather than the strict eye/hand method of viewshed mapping, this project was assisted by the computer system VIEWIT. The VIEWIT system aids visual resource analysis by its ability to locate and map visible terrain from a single location or series of locations, called viewpoints. By using a series of 450 viewpoints along the length of the River, and by merging the viewshed of each viewpoint into one total viewshed, the entire area which can be seen from the River was recorded.

VIEWIT
VIEWIT

VIEWIT

As its most basic function, VIEWIT maps those areas which can be seen from user specified viewpoints. These visible areas are printed on maps which show the total number of times each area was seen, relative to the number of viewpoints and their location on the map. The visual analysis of the Missouri River in this project uses this basic function.

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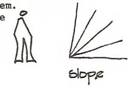
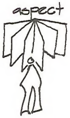
* Travis, Michael R., Gary H. Elsner, Wayne D. Iverson, and Christine G. Johnson.
1975. VIEWIT: computation of seen areas, slope, and aspect for land-use planning. USDA Forest Serv. Gen. Tech. Rep. PSW-11, 70 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

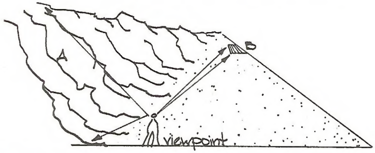
Several other functions are also possible in using the VIEWIT system. Area slopes and aspects may be determined and mapped using the same elevation information as the basic viewshed function. The quick generation of this data has been demonstrated to be useful in watershed management, erosion control, forestry activities, etc. In terms of visual resource management, these functions may be interactively combined with the viewshed mapping function and distance from viewpoint weighting function. This allows further quantification of visual sensitivity and vulnerability of different areas within the viewshed.





For example, an area which is:

A - close to the viewpoint
  - with a large slope towards the viewpoint
  - with an aspect perpendicular with the viewpoint
would be most heavily weighted in terms of its overall visual vulnerability, (most likely a cliff being faced head-on).



Conversely, an area which is:

B - at a great distance from the viewpoint
  - with a small slope towards the viewpoint
  - with an aspect turned away from the viewpoint
would be the least weighted area in the viewshed in terms of its visual vulnerability, (most likely a distant area in a prairie landscape).

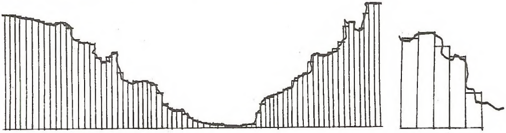
Combining these several functions to produce a single output map may be dangerous. Complex and subtle implications can appear which must be understood by the user so that he can use the output correctly and most efficiently. The VIEWIT Users Manual will most likely be the greatest help here.

As a note, the concept of visual sensitivity rests on the premise that if a structure were to be built within the viewshed, it would have a greater visual impact in some areas than in others. By locating the areas of lowest to highest visual sensitivity, we could attempt to site the structure in the area of least visual sensitivity. It would be easier then to mitigate the visual impacts of the structure than if it were in a highly sensitive zone. Analyzing the actual visual characteristics of the structure itself would help in the siting process.

There are many other possible inputs to, and implications of, visual sensitivity zones (preference, uniqueness, etc.), but such a monumental discussion is not within the scope of this report. Let us simply say that each project must determine for itself those inputs and implications most relevant to its own intents and purposes.

ELEVATION BASE

Before using a computer system such as VIEWIT, the elevation information on a standard contour map must be converted to a form which can be recognized by the computer. VIEWIT uses a grid system topography in which each grid cell is 1/5" long and 1/6" high. On the standard USGS 7-1/2 minute quad maps used in this project, this translates to a scale of 333' x 400', or an area of 3.1 acres per grid cell. Thus, the transformed elevation map appears to be a giant blocked landscape where each block, or grid cell, has its own single elevation.



The grid cell elevation base for this project was acquired from the Defense Mapping Agency (DMA) in the form of computer tapes. These tapes must be translated in order to produce the gridded elevation maps compatible with the VIEWIT system. This process is discussed in a later section.

The specifications of these DMA tapes do not exhibit a great degree of accuracy or detail. Large projects requiring less detail will find these tapes to be an acceptable source of elevation data, especially in terms of cost. Alternate means of acquiring a topographic data base include in-house hand digitizing and contract digitizing. Though the accuracy achieved with these options can be greater, time and money costs are also much greater, being prohibitive in a project as large as this. Small projects needing a great degree of accuracy and detail are best suited to these alternatives.

Orthographic Projection, a system which promises to produce exact grid cell elevation maps from aerial photography (at a reasonable cost), should soon be available for both large and small scale applications.

DETAIL / ERROR MARGINS

Before taking a closer look at the characteristics of DMA elevation data, there are several more basic issues which should be addressed.

The VIEWIT system is used to produce maps which provide for and function as a multi-purpose planning and management tool. VIEWIT is an analysis tool; it is not the product in itself, rather one step in the process which leads to the final product. The final product of this process is a management plan which protects the scenic quality of the Upper Missouri River.

In addition, unlike most other analysis systems, the VIEWIT system can remain active, serving in long term planning activities and site selection. The system can respond to new criteria and issues which may evolve in relation to this project.

In a simplified form, there are three basic steps in this project's process to produce the analysis maps:

1. Gathering the base data upon which the analysis is founded and supported, and organizing that data into a useable form. (Acquiring and translating the DMA tapes and gaining access to the VIEWIT system.)
2. Manipulating that data and performing the analysis. (Creating the elevation maps and subsequent VIEWIT runs using those maps.)
3. Preparing, reviewing and interpreting this analysis to provide for its best use. (Includes preparing visual vulnerability maps.)

Recognizing these basic steps, there are several considerations which should be kept in mind while involved in an analytic project such as this. One of these is the predetermination and understanding of the error margins contained in the base data and the system which manipulates that data, (completely depending on it). Recognizing these error margins, we can establish the degree of reliability of the analysis, or how far and to what level of detail we can trust the final VIEWIT maps. This helps then in deciding what the possible and best uses of these maps should be.

Determining error margins rests on the principle that the final output of the analysis, which dictates the final use of the analysis, is only as reliable as the base data input and the system which produces that analysis. So, reliable base data manipulated by a reliable system is the only way to produce a viable analysis. Obviously you will get out what you put in.

Related to the error margins of the project is the level of detail within each phase of the process. Looking at the entire project, the levels of detail within each phase of the project should balance. This allows for the most efficient use of time and resources. Unnecessary actions are avoided, fewer information gaps appear in the process, and its simply easier to refer back and look ahead to the other steps in the process.

For instance, if we collect base data for the project which is more detailed than the intended uses of that data, we are wasting time with detail and complexity which is unnecessary and/or unuseable. As a more common problem, if the detail of the base data is too general, the final analysis will be too ambiguous for the intended uses of the analysis. So the person using the analysis is forced to make detailed decisions which are no more than assumptions based on a gross analysis. This defeats the primary goal of the analysis which is to remove ambiguities so that clear, supported decisions can be made.

So a balance of detail throughout the project, from start to finish, will make for the most useable product, produced in the most efficient way.

It becomes readily apparent that to make sure the final product is in its most useable form, the largest acceptable error margins and levels of detail should be determined at the time the project is initiated. When we know what these limits and bounds of the final product should be, we can check whether the available data detail and error margins are acceptable for the intended uses.

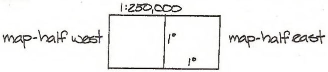
Then we can choose an analytical tool (such as VIEWIT) and a source of base data (such as DMA tapes) which best serve the intents and purposes of the final analysis. Therefore, balancing the analytical tool with the final product we need will match the detail of the project's input to the detail of the output, which is needed for the detail of decisions which have to be made using that product.

In the final evaluation, the value of the end product is determined by how the level of detail in the data and the extent (and importance) of the error margins will help or hinder the decisions which will be made using that end product.

DMA CHARACTER

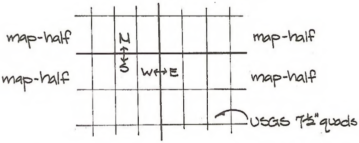
With these basic issues in mind, we will now point out several characteristics of DMA elevation information that we observed in this project. As mentioned earlier, DMA data is used in a grid cell format of 3.1 acre rectangles, each assigned its own single elevation.

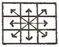
DMA information has been interpolated from USGS 1:250,000 scale maps. Each 1:250,000 map is 1° in latitude by 2° in longitude. The DMA tapes are setup so that each file on the tape contains a 1° x 1° portion of the earth's surface, that is, two files for each 1:250,000 map. These are specified as map-half east or map-half west.



The files specify elevation values on a 200' grid. To convert this 200' grid to our 333' x 400' rectangles, we used the TOPAS computer program COPYNCIC, which is simple to use, but quite expensive. An example of the input format for this step is included in the appendix.

A complex situation occurs when the study area is contained within two or more adjacent map-halves, thus different data files. Joining the east and west portions of the study area is most easily accomplished. Since the data on the tapes in stored by columns, the east portion of the study area can be added to the west portion by using the Univac Text Editer. It becomes more difficult to join concurrent north-south map halves due to this "by column" format of data. The TOPAS programs SCANDTIS and ARRAY can be used to accomplish this step. Because of the time and cost parameters of this project, these programs were not used for this study. This has implications in the final uses of the output, and will be discussed later.

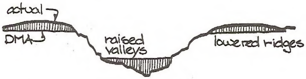




In more detail, DMA information has a maximum deviation of no more than 400' for any spot elevation on the horizontal plane. When considered in light of our grid cell size, this means that any cell may be off no more than one cell in any direction. Also as specified, the error in the vertical dimension may be off no more than 100'.

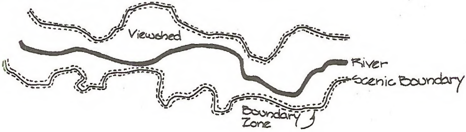
When these error margins are considered within the steep topography of the Missouri River Basin Landscape, the total effect on the accuracy of the mapped viewshed will generally be insignificant. This error margin could obviously be much more devastating on a flatter, undulating landscape.

Another problem we observed in using DMA information is that of truncation. With the characteristic topographic averaging, the extreme lows of a valley floor, or the high elevations of a ridge line are averaged to less extreme elevations. For example, a V-shaped valley may be interpolated to a trapezoidal shaped valley within the DMA tape. This problem should be remembered in reviewing the final VIEWIT maps.

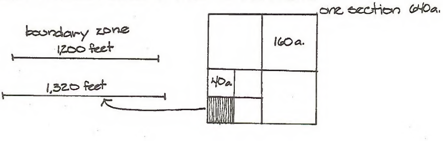


Also, the first elevation maps from the DMA tapes should be carefully checked to make sure the topography has not shifted to an incorrect location. Spot checking major land forms, and high and low elevations will quickly aid in this process.

In the final review, we can see that the DMA tapes serve the functions of this project within the allowable error margins. The combined error margin within the DMA detail, both horizontal and vertical, will probably never exceed three cells. Rather than producing a boundary "line" for the River's viewshed, we know that the true boundary exists within a zone of three or four cells along the mapped rim-to-rim boundary. Since the low elevations of the River are mapped somewhat higher and the high elevations of the rims are mapped somewhat lower, we know that the mapped viewshed is a maximum viewshed. This then ensures that the total viewshed has been mapped.



And finally, the legal boundary for this Wild and Scenic River will be mapped at a level of detail not less than the 40 acre subunit of the 640 acre (square mile) sections of the region. This 40 acre subunit has a dimension of 1,320 feet on a side. The possible VIEWIT zone of the rim-to-rim boundary should not exceed three cells or 1,200 feet. These considerations should thus ensure an adequate balance of detail for this project.

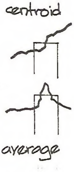


HAND DIGITIZING

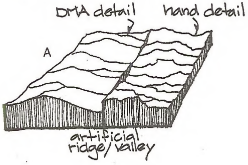
With the detail implications of DMA tapes well understood, it is easily conceivable that much more exacting elevation information may be desired for certain uses of the final output. For instance, a more complex analysis may be desirable for site selection of land uses or such things as the corridor selection of roads or powerlines. More detailed elevation and slope information with

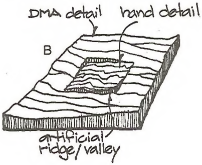
lesser margins of error can be achieved through a variety of means, including hand digitized information. These methods are also useful when an obvious locational error occurs within the DMA information.

Hand digitizing elevation data is a time consuming and somewhat tedious process. Its use should be limited to smaller areas. Either centroid or average elevation coding can be used with this method.



As hand digitized data is more accurate than DMA elevation data (assuming the person hand coding the elevation fully understands the task), the implications of joining the two, that is, using them side by side, must be considered. The more accurate in relation to the less accurate will most likely cause an artificial ridge/valley line along the joint.





A Where the DMA and hand produced data occur on two separate maps, the VIEWIT viewshed will be skewed along the joined edge. This shifted condition of the viewshed must be compensated by interpolating the viewshed along the joint to its most accurate position. This can be accomplished by paying close attention to the more accurate map, along with the relationships of the contours from one map to the next.

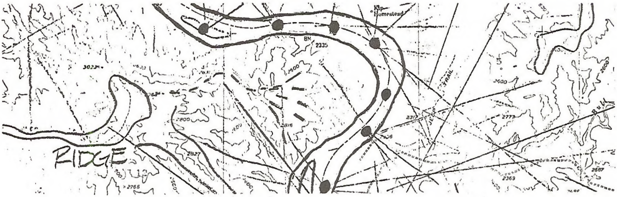
B When both methods are combined onto a single map, the VIEWIT output will most likely be skewed along all the joints. The presence and degree of the problem in specific situations will dictate what actions will be necessary. Either an artificial smoothing of the elevations along the joints prior to the analysis or an averaging of the viewshed location after the analysis may be deemed most appropriate.

BACKGROUND

At this point in the project, we were ready to establish the exact boundaries for the study area along the River. Because DMA data and VIEWIT could be used most easily at the USGS 7-1/2 minute quadrangle scale, providing a satisfactory analysis, we used a study area based on the entire quadrangle maps which contained the River or its probable viewshed.

At this time, we made a quad by quad review of the area, marking highest and lowest elevations, along with an initial estimate of what areas might occur in the viewshed. We also made a preliminary estimation of where the most appropriate viewpoints might occur in order to map the complete viewshed. During this review, a record was kept which included for each quad:

1. The high and low elevation
2. The difference between the two
3. The preliminary estimate of the total number of viewpoints, with room for revised totals

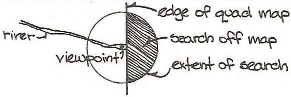


VIEWPOINTS				ELEVATIONS		
	15	21	P and N Ranch	3400'	2400'	1000'
3rd	2nd	1st	Quad Name	High elev.	Low elev.	Interval
Estimate						

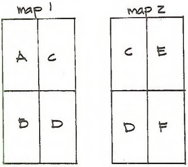
The purpose of this record was to assist in selecting elevation intervals, and to keep a running total of the viewpoints for cost estimates and later project evaluation.

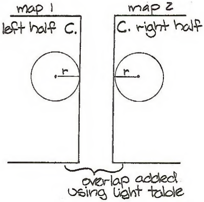
Upon completing this review, we then considered the total number and area of the aggregate maps we would use in the project. This presented a problem in study area continuity since the area of the project was so large.

The storage capacity in using VIEWIT limited us to a total map area of four total quads. Since there are 26 quads to be used in this long, linear study area, the how and where of joining these maps had to be considered next. This presented an important problem. If viewpoints are placed to the very edge of a map, the areas which can be seen from that viewpoint, but exist on an adjacent map, will remain unrecorded. In order not to lose this information and to maintain a high level of accuracy, a system of overlap was developed. The area of overlap consists of entire quad maps.



For example, the first aggregate map in the study area consists of quad maps A, B, C and D. By this overlap method, the next aggregate map would consist of quads C, D, E and F, where quads C and D would appear both in the first and second aggregate map. Likewise, the third map would consist of quads E, F, G and H, and so on.





Using this system then, the radius of the search from a viewpoint (r), should equal the distance that last viewpoint is placed from the edge of an overlapping map. A seen area is never lost by a viewpoint "looking off the map." By overlapping map one (CD) onto map two (CD), the total seen area along that section of the River is accurately recorded.

The disadvantage of this method occurs as the total number of aggregate maps for the study area is almost doubled. Also, when figuring the total number of times seen for a cell within the overlap, we are forced to add the numbers from both maps using a light table. This is time consuming. The greater accuracy achieved overrode this inconvenience and slightly higher costs for this project.

Also, due to the problem of overlapping the 1° x 1° DMA map halves as discussed earlier, the overlap of aggregate maps was not always possible for this project. Several joints do occur which must be interpolated for purposes of continuity.

ELEVATION MAPS

As mentioned before, the DMA elevation information is converted to the grid cell size of 3.1 acres by using the TOPAS program COPYNCIC. A map of the coordinates of each quad in the DMA 1° x 1° file can be obtained by using the TOPAS program PRINT. An example of this output is included in the appendix.

The task now is to create the four-quad aggregate maps on which VIEWIT can function. The STAR*GRID program (PSW*VIEWIT.DMA) groups this information into the desired aggregate maps, and stores them under a user-specified name. In order to use STAR*GRID, we specify which DMA map-half contains the desired aggregate, and whether it is an east or west data file. The number of rows and columns which appear on this map must also be specified. An example of this computation also appears in the appendix. The x,y coordinates of the southwest corner of the desired aggregate map must also be specified as they appear on the PRINT output, expressed in hundredths of an inch.

When STAR*GRID has been successfully performed to create the new hase map, we have the option of immediately specifying elevation classes, and producing an elevation map. This map is numerically coded, based on our elevation classes. A cell in interval "1" receives a "1," a cell in interval "2" receives a "2" and so on.

The purposes of producing these elevation maps from the newly created files which contain them are first, to ensure that the desired area has been correctly transferred from the DMA map-half, and secondly, to check the accuracy of the elevation information (by class) with the correct placement of major landforms. Finally, to provide a gridded base map of the area with which the user can accurately determine the x,y coordinates of the viewpoints which are to be specified in the subsequent VIEWIT runs.

The VIEWIT program uses the actual elevation files which are created as the base from which seen areas are mapped, not the intervals of the elevation maps which have been produced. Thus, the main objective to consider in producing the maps themselves is to render them as clear and readable as possible. This helps in the checking and verification of information process.

The actual assignment of elevation classes is dependent on the total difference in elevation between the high and low points, which features are to be accentuated, and the detail of the topographic landscape. Remembering the character and detail of our DMA tapes, the limits of our intervals should not be less than 50 feet or greater than 300 feet, for the greatest readability. One example of the intervals used for one map in this project are as follows:

interval	range	
1	2400 - 2449	: river elevation range
2	2450 - 2549	landecape elevations
3	2550 - 2649	
4	2650 - 2749	
5	2750 - 2849	
6	2850 - 2949	
7	2950 - 3049	
8	3050 - 3149	
9	3150 - 3249	
10	2000 - 2399	: show low elevation mistakes
0	3250 - 3500	: show high elevation mistakes

The number of user specified elevation classes should ideally be limited to nine or less. Double digit numeric maps are very difficult to read. Also, the file names assigned to each of these maps should be logical and closely cataloged. This ensures their correct assignment and use in the subsequent VIEWIT operations.

A total of 17 aggregate maps were thus produced for this project, ranging from two to four USGS quad maps per aggregate map. A listing of these follows in the appendix.

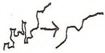
VIEWPOINTS

When the elevation maps had been produced and verified, the next step was to determine the final viewpoint locations for use in the VIEWIT runs. This selection process is perhaps the most critical step in the entire project process. This follows since the final VIEWIT output is the direct result of the combined functions of each viewpoint, its own location and relation to the adjacent viewpoints.

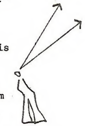
In the preliminary review, we tended to include more viewpoints than are really necessary for optimal coverage of the viewshed in the most efficient means. The mind cannot see, from the plan view, the complete potential of each viewpoint with the same totality and speed characteristic of the computer. This limitation creates a tendency for the user to oversaturate the study area, not allowing for maximum efficiency.

The goal in this selection process is to strike the balance between input and output, to reach the fine line where we have total coverage of the viewshed without unnecessary, repetitious viewpoints. Then we have accomplished the most efficient use of our time and the system.

In order to eliminate unnecessary viewpoints, we took into account two basic factors. First, we considered the characteristics of our elevation base data which VIEWIT uses. The DMA information is a system of averaged elevations within grid cells. The complex features of the terrain are averaged into a single elevation for each cell. We do not have to keep in mind every bump and tiny undulation in the study area.



This becomes, in fact, one advantage of this system. A total approach to the landscape ignores the tiny details by reviewing the whole. These small deviations would most likely be included in the final viewshed even if considered, but since they are averaged out, allow the system to function at a more simple, less costly level, with comparable results.

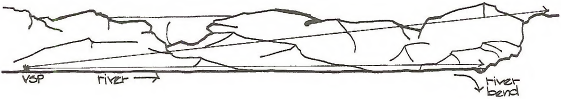


Secondly, a more important consideration in choosing viewpoints is the actual character of the study area terrain. Within the Missouri River Basin, a viewer is dominated by steep slopes and cliffs which rise ruggedly from the River in a closed rim-to-rim landscape. The viewer is inferior, that being the position from which he must look upwards to perceive the landscape.

From this position, and within this terrain, we found that there are three basic types of views perceived from the River. We used these three types of views in a methodology for placing viewpoints along the River. The three basic types of views are from Visual Sequence Points, Intermediary Points and Break Points.

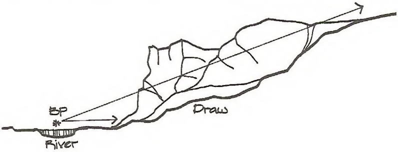
Visual Sequence Points

From the visual sequence points, the observer can see the longest views possible along the River corridor. These points occur at the locations where the River bends, opening up new and distant views parallel with the River. And since the views are long, the angle of observation is the smallest. This allows the observer to have views which include portions of the larger landscape beyond the immediate wall-like topography along the River. Thus, a distant, potentially grandiose view is possible, providing a wide lateral angle which allows a more comprehensive perception of the landscape whole. There are not a large number of views along the River, and those that do occur are even more important to map because of this unique visual experience in a closed landscape.



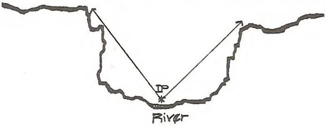
Break Points

The break points occur at those locations where the eroded draws have broken the immediate wall-like topography of the River landscape. The observe has moderate distance views towards areas beyond the River landscape, but more narrow in scope. The frequency of the views allow for a more varied visual experience along the river. These areas of visual variety should be carefully mapped in order to include them within the viewshed, even though the actual amount of time they can be observed may be relatively short.



Intermediate Points

We complete the coverage of the total viewshed by using the intermediary viewpoints. These points function in order to fully scan the immediate topography along the River, generally occuring in those intervals between the previously mentioned types. During our initial review of the terrain in this River region, we decided that the maximum interval between viewpoints should not exceed one quarter mile. By careful placement of these viewpoints, the viewshed of the River was completed.



By applying this placement methodology, based on view types as defined by the possible views within the terrain, we mapped the total viewshed from the 149 mile stretch of the River by using a total of 450 viewpoints.

It becomes obvious also that the role of a single viewpoint can encompass any combination of the roles described above for the three view types. The possible combinations include:

1. Intermediary Point
2. Intermediary Point and Visual Sequency Point
3. Intermediary Point and Break Point
4. Intermediary Point, Visual Sequency Point and Break Point

Thus, only the intermediary point can ever function as an entity, while the visual sequence points and break points also perform as intermediary points. And certain viewpoints even act as all three. This overlap allows elimination of duplicating viewpoints.

RADII

Keeping in mind the three basic types of viewpoints and the role of each, we can assign the radius (limit) of the search for visible terrain which the computer uses in the VIEWIT run. Since the role or roles of each viewpoint have been determined in our placement methodology, we need only measure the farthest possible viewing distance from the viewpoints to know what the radius of search should be. We included within the radius those areas which were questionable, since a viewshed map that has not mapped the farthest extents of seen areas is functionally useless in our boundary mapping.

In this project, our maximum radius was ten miles and our smallest three miles. The visual sequence points, by definition, had the largest radii, being six, eight or ten miles. The break points were generally assigned a more moderate distance, usually four or six miles, with some three, eight and ten mile searches for unique situations. The intermediate points were always assigned a three mile radius of search.

Due to the rugged topography and ambiguous viewshed judgements caused by such a topography, we maintained the three mile minimum so we would not be fooled and not search far enough. This system of assigning radii for each viewpoint helped us maintain as accurate and complete a set of final maps as we could achieve using the VIEWIT method.

VIEWIT

With the locations and radii of the viewpoints finalized, we transferred these points onto the elevation maps which we created earlier. We accomplished this on a light table by overlaying the USGS quad map transparencies (with viewpoints drawn on) onto the elevation map computer printouts. Then the row and column number of the viewpoint, along with its radius, can be entered into a VIEWIT run-stream. An example is included in the appendix. The actual format user's options can be found in the VIEWIT User's Manual, (Elsner, 1968).
We also used a ZBIAS of six feet. This command allows us to raise our viewpoints six feet above the surface of the river. We used this option to simulate a more real-life situation, as if a floater were to be in a canoe or boat on the river.

MAP DISPLAYS

We can then choose among several ways in which the VIEWIT maps can be displayed. One of these alternatives must be specified at the end of the VIEWIT run-stream. Choosing among these methods depends on the intended uses of these viewshed maps.

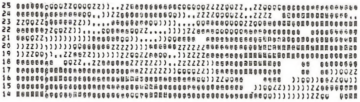
The two line-printer options are grey scale maps and numeric maps. The major option to consider is whether to map the actual number of times seen for each cell in the viewshed, or the average number of times seen for each cell in the viewshed per the total number of viewpoints on the map.

Grey Scale Maps

Grey scale maps are a graphic display, in nine shades of grey, which show the number of times seen for each cell in the viewshed. It is a map composed of symbols, where the greater number of times a cell is "seen" from the viewpoints on that map, the more "dense" will be the symbol in that cell, the darker will be its shade of grey.

Option: Actual Number of Times Seen (G MAP)

Using this option, a cell inside the viewshed which is seen once will be mapped with the grey scale symbol "1," a cell "seen" twice will be mapped grey scale symbol "2," and so on. By this method, the number of viewpoints on the map cannot exceed nine since any cell "seen" nine or more times is mapped by the very dark grey shade symbol "9." If the user wants any cell "seen" nine or more times to be mapped the same way, this option will give the desired results. The VIEWIT symbol set is the restraint in this case. There are no larger symbol sets currently available for normal use in this system.

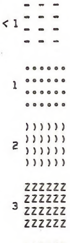


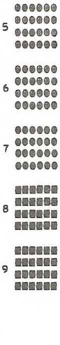
Option: Average Number of Times Seen (AVG MAP, G MAP)

Using this option, the total number of viewpoints on the map are grouped into ten intervals, ranging from less than one time "seen" (0-4 percent) all the way up to 85-100 percent of the time "seen." This breakdown is represented in the chart below:

Viewpoint Totals for project maps

Grey Scale	14	18	20	22	24	25	26	27	35	38	42	52
<1			1	1	1	1	1	1	1	1	1-2	1-2
1	1-2	1-2	2-3	2-3	2-3	2-3	2-3	2-4	2-5	2-5	3-6	3-7
2	3	3-4	4-5	4-5	4-6	4-6	4-6	5-6	6-8	6-9	7-10	8-15
3	4	5-6	6-7	6-7	7-8	7-8	7-9	7-9	9-12	10-13	11-14	14-18
4	5-6	7-8	8-9	8-9	9-10	9-11	10-11	10-12	13-15	14-17	15-18	19-23
5	7	10	10-11	10-12	11-15	12-13	12-14	13-14	16-19	18-20	19-23	24-28
6	8-9	11	12-13	13-14	14-15	14-16	15-16	15-17	20-22	21-24		
7	10	12-13	14-15	15-16	16-18	17-18	17-19	18-20	23-26	25-28		
8	11	14-15	16-17	17-18	19-20	19-21	20-22	21-22	27-29			
9	12-14	16-18	18-20	19-22	21-24	22-25	23-26	23-27				





The total number of viewpoints across the top of this chart are the totals for the maps in this project. For example, by referring to the column of numbers below the viewpoint total of 38, we can see that the "less than one" grey shade represents those cells seen by one viewpoint on that map, the grey shade symbol for interval "1" represents those cells "seen" by 2-5 viewpoints, and the symbol for interval "2" represents those cells "seen" by 6-9 viewpoints and so on.

We can see that the grey shades here demonstrate a range of times seen for each cell, not the actual totals. Also, since this option does tend to average out those cells at the low end of the scale (0-4 percent) the command SHOW NZ should be used in the VIEWIT run-stream. This option will map the less-than-one range with its own symbol, a very light grey shade (-). If not used, the cells within this 0-4 percent interval will remain unmapped, even though they were "seen."

There are several inherent problems with this option. For this project, it becomes obvious that because there is a different total of viewpoints for each map, the number of times seen intervals will vary from one map to the next. This means that the grey shade symbol for interval "5" will represent a range of times seen which is different than the range of times seen represented by the same symbol on the next map. The line through the chart that shows in which interval a cell "seen" 12 times will occur for each map in this project readily points to this problem. Relating one map in the project to the next becomes very difficult. The process of overlaying our aggregate maps, as discussed earlier, becomes virtually impossible.

Ideally, we should use this option only when we are producing a single map, not a contiguous series, unless of course, all maps have the same total number of viewpoints (quite unlikely). In spite of the problem, this option is useful for large group/public presentations since the graphic display of light and dark can be recognized from a limited distance, where dark vs light means something.

Keeping in mind the shifts in symbolism from one map to the next, a quick spotcheck of the darker, more often "seen" areas can give the user a general ides of where the more visually vulnerable areas do occur. Scenic boundaries are also very easily determined from these maps.

As a note, there is unfortunately no user option within the VIEWIT system which allows us to specify a uniform range of intervals for number of times seen that can be applied to a series of maps such as these. Such an option would be most valuable in mapping uniform intervals for all maps even though the total number of viewpoints may change from map to map.

Numeric Maps

Numeric maps are also a graphic display produced on a computer line-printer. Rather than using symbols to represent shades of grey, these maps display the actual number of viewpoints which could "see" each cell within the viewshed, or the numeric percent of times seen based on the total number of viewpoints on that map.

Option: Actual Number of Times Seen (MAP)

With this option, the exact number of viewpoints which can "see" any cell within the viewshed is printed in that cell. Rather than a grey scale symbol which represents an interval of times "seen," such as 6-9, the actual number will appear in that cell, such as 7.

Achieving this level of detail may be important for such tasks as selecting a site for a land use which must occur inside the viewshed. Then the difference between a cell being "seen" six or seven times can be quite important.

The major problem with this option stems from the general legibility of these maps. Since numeric maps are large conglomerations of one and two digit numbers in contiguous masses of cells, the entire output tends to grey out visually into a meaningless mass. We have to rely on a grid overlay and close inspection in order to comprehend this output and use it efficiently. It is impossible to read these maps from any distance, thus ruling out their use for public display.

Numeric maps are most useful for in-office planning processes and functions. They relate well to each other in a long sequence, as is the case in this project. Also, the overlap method discussed earlier is best served by these maps, since they can be overlayed on a light table.

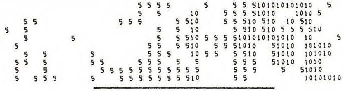
```
 7 7 7 6 6 6 6 6 6 6 7 7 7 7 6 6 7 911 1 1 4 5 6 7 8 812 311 610111011111111111111010
 8 8 7 6 6 6 6 6 6 6 7 7 6 7 7 7 8 8 910 8 6101010 9 9 2 6111111111111111111111101010
 8 8 7 7 6 6 6 6 6 6 6 7 7 7 7 7 8 8 910101311121111 712121111111111111111111010 9 8
 8 8 7 7 6 6 6 6 6 6 6 7 7 7 7 7 8 8 8101011141313 7 7 8111111111111111111110 9 6 6 6
 8 8 7 7 7 6 6 6 6 6 6 6 7 7 7 7 8 8 8 91010111512101212111111111111111 9 8 9 9 6 6
 7 7 6 7 7 6 6 6 6 6 6 6 7 7 7 7 8 7 8 9 91112171212121211111111111111 6 7 9 9 8 4 5
 7 7 6 6 6 6 6 6 6 6 6 6 6 7 7 7 8 8 8 9 91012 91512121111111111111111 6 6 9 7 9 6 4
 7 7 6 6 6 6 5 6 6 6 6 6 6 7 7 7 8 8 8 8 910121411121211101111111111 7 7 5 6 8 9 5 4
 7 7 7 6 6 5 3 5 5 6 6 3 5 6 7 7 8 8 8 8 91012131312111111111111110 8 6 6 3 5 7 8 5 5
 7 7 7 7 7 7 5 4 5 3 3 3 4 3 6 7 8 8 8 810 712 812121111111111101010 6 6 5 4 8 8 5 5
```

Option: Average Number of Times Seen (AVG MAP, MAP)

This option creates the same intervals of times "seen" for cells within the viewshed, as discussed for the grey scale average maps. The main difference is the type of output which is numeric rather than symbolic. For instance, if a cell is "seen" by half the viewpoints on the map, that cell receives a "5," and if "seen" by all viewpoints, it receives a "10."

The advantage of this system is its immediate translation of number of times "seen" into a numeric percent of the total viewpoints on that map. This is useful for small numbers of viewpoints, where the user wishes to interpret the viewshed based on a percent of the total that any area is "seen."

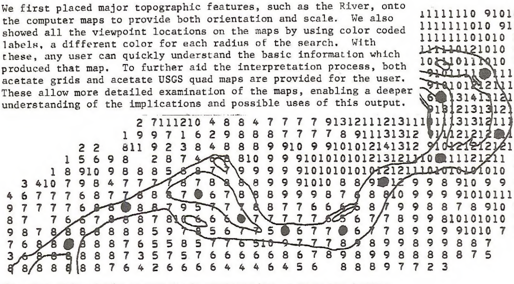
These maps become increasingly messy as the user increases the total number of viewpoints on the map. Also, these maps are quite difficult to read, having the same graphic problems discussed earlier.



MAP PREPARATION

With the completion of this process which produces the final output, we now have a set of computer maps which show the viewshed of the Missouri River. To make sure we receive the maximum benefits from all our efforts, a complete understanding of these maps, with proper interpretation and a realization of the total implications of the data is imperative. Then we can achieve the maximum benefits and efficiency, the highest uses allowed by this system.

We first placed major topographic features, such as the River, onto the computer maps to provide both orientation and scale. We also showed all the viewpoint locations on the maps by using color coded labels, a different color for each radius of the search. With these, any user can quickly understand the basic information which produced that map. To further aid the interpretation process, both acetate grids and acetate USGS quad maps are provided for the user. These allow more detailed examination of the maps, enabling a deeper understanding of the implications and possible uses of this output.



By using this simple computer map preparation, a user can better understand how the maps were made, what they mean and how they can be used.

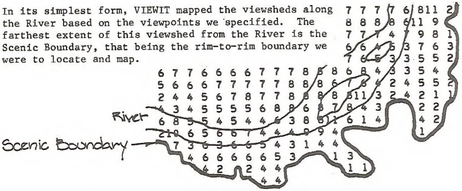
SYSTEM USES

There are several specific uses of this data which relate to the intents of this project. The following are those used during this project and as ongoing possibilities with a system such as VIEWIT.

1. Scenic Boundaries

This application of the viewshed maps is perhaps the simplest, but by no means the least important. This, in fact, was the major objective of this project, with the alternate uses being beneficial potential by-products of a system such as VIEWIT.

In its simplest form, VIEWIT mapped the viewsheds along the River based on the viewpoints we specified. The farthest extent of this viewshed from the River is the Scenic Boundary, that being the rim-to-rim boundary we were to locate and map.

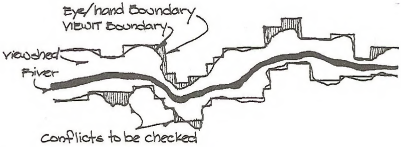


Before using this system, scenic boundaries were determined by hand/map methods, based on field and topographic map observations. By floating down the River and spot checking with a helicopter, general "seen areas" are noted on a base map of the region. Unlike the computer method, this system does not allow for a complete and comprehensive scan from a large number of viewpoints.

There is a tendency with this method to consider only the shorter views. This means that many areas which can only be seen from greater distances will remain unmapped. Also, it becomes hard to map the landscape seen in three dimensions onto a two dimension base map. These judgment errors make necessary more generalized scenic boundaries. The scenic boundaries interpreted from VIEWIT viewshed maps are based on a much greater degree of detail. (For a more detailed comparison of eye/hand, sectional and VIEWIT techniques, see "Landscape Control Points," Paper PSW-91, USFS, Litton, 1973.)

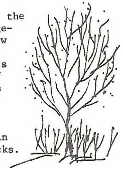
As a comparison, the scenic rim-to-rim boundaries mapped with the eye/hand method were overlayed with the boundaries derived from the VIEWIT viewshed maps. Overall, we found that the two boundaries were more similar than different. There were several major areas of conflict with more frequent smaller conflicts.

We found that these discrepancies were both areas included within the eye/hand derived boundaries but not considered visible by VIEWIT and areas outside the eye/hand boundaries which were recorded as visible by the VIEWIT method.



The comparison is difficult to make since the eye/hand method maps the scenic boundaries on a 40 acre grid, as mentioned earlier, while the VIEWIT boundaries are strictly landform derived and must be interpolated to the 40 acre gridded boundary definition.

Beyond the basic system differences discussed earlier, the major reason for these differences is the areas of vegetation along the River. This vegetation does not allow for adequate eye/hand mapping of potentially visible terrain, while the VIEWIT system ignores these elements in its search. This becomes an important advantage of VIEWIT in this project area, where these wooded blinds are cottonwood trees, a characteristically transitory element in the landscape.



To determine the most accurate final scenic boundary in these conflict areas, we employ a series of field checks. Verifying these boundaries is not always an easy task. For instance, the area in question may be visible from only one location along the River. We must make an adequate search for that location to determine whether or not the area in question is really inside the viewshed of the River. Also, we can see that when the VIEWIT derived boundary is generalized to the 40 acre boundary definition, many of the smaller conflict areas disappear. This relates back to our earlier discussion of detail levels and error margins.

In a practical sense, we want to avoid excluding seen areas from the final scenic boundary. This could mean that a land use could occur in that area which would be unregulated and remain unmanaged. Thus it could potentially have an adverse impact on the scenic quality of the River. By the same right, including areas within the scenic boundaries which are not visible means unnecessary acquisition costs, restrictions and management costs.

Finally, if determining scenic boundaries is the sole intended use of the VIEWIT maps, grey scale maps will provide the most readable and useful tool.

2. Visual Vulnerability

By character on the Congressional definition of the Missouri River as a Wild and Scenic River, any area within the scenic rim-to-rim boundary is classified as "A" scenery by the BLM's Visual Resource Management System. This implies no differentiation of areas within the scenic boundaries. The eye/hand method of drawing scenic boundaries tends to reinforce this nondistinction typology.

Using VIEWIT maps, we can take this analysis one step farther. On these maps, the number of viewpoints which "see" an area is recorded in every cell of the viewshed. Though this does not take into account the quality of the view, it does make it possible for us to rank these areas based on how often, thus how long they can be seen. By this principle, if an area is seen more times, it is seen longer and is consequently more visible. Based strictly on time, the areas which are most visible have a higher visual vulnerability than those areas which are less visible. These areas must then be more carefully managed since an activity which occurs in those highly visible areas could have a greater impact on the scenic quality of the River. Though oversimplified, this concept can be useful in the management activities along the River.

In mapping relative visual vulnerability along the River, we assumed that:

A. To be used as a planning tool for siting necessary structures and activities in the viewshed, areas of lowest visual vulnerability should be shown in more detail. More distinctions should be drawn at this end of the scale between the number of times seen.

   Low number of times seen: less amount of time visible; lowest possible impacts on scenic quality; more attractive sites for an activity.

   High number of times seen: greater amount of time visible; higher possible impacts on scenic quality; less attractive sites for an activity.

B. Management on areas of higher visual vulnerability requires fewer distinctions. Lengths of time seen tend to lose significance as they increase. The difference between 60 and 70 minutes of visibility is academic for siting and controlling impacts on scenic quality.

Applying these basic assumptions, we mapped the visual vulnerability zones based on the following classes:

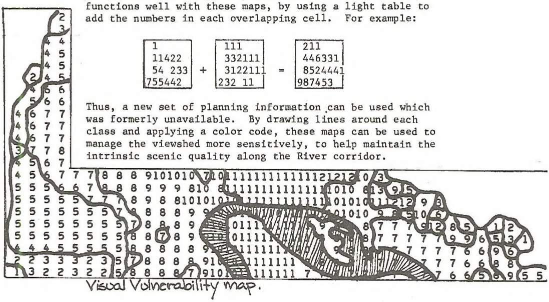
TIMES SEEN
1.....5
2-3.....10-15
4-5.....20-25
6-7.....30-35
8-10.....40-50
11-14.....55-70
15-18.....75-90
19+.....95-2 hrs +

Approximate minutes of visibility, based on a river speed of four miles per hour.

Numeric maps are the best map alternative for establishing these levels of visual vulnerability. Our overlap system functions well with these maps, by using a light table to add the numbers in each overlapping cell. For example:

```
1               111              211
 11422           332111           446331
  54 233    +     3122111    =     8524441
755442          232 11           987453
```

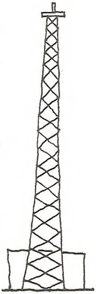
Thus, a new set of planning information can be used which was formerly unavailable. By drawing lines around each class and applying a color code, these maps can be used to manage the viewshed more sensitively, to help maintain the intrinsic scenic quality along the River corridor.



Visual Vulnerability map.

3. Planning/Design Decisions

When a siting decision for a land use or activity has been made within the viewshed of the River, its visibility and visual impact can be measured with the help of VIEWIT. If we place a viewpoint on the uppermost structure of a land use, like the top of a utility pole, bridge or well, we can map all areas from which that structure may be visible. This can be the base from which other issues can be considered such as possible versus probable perception, screening and the like.



This technique can be used for choosing several possible sites and then narrowing them down to the one at which the visual impacts on the River will be the least. This should be an important part of the site analysis and selection criteria.

We can use this same method to develop trail/overlook systems along the River, such as in the Hole-in-the-Wall area. This can help select the most panoramic views while making sure the networks of trails do not adversely impact the natural scenic quality of the region.

It should also be noted that detailed decisions such as these probably necessitate more exact elevation data such as that produced by hand digitizing methods.

CONCLUSION

In the final review of this project, a process for creating this analytical tool with its subsequent applications, there are several conclusions and recommendations we can point out.

First of all, the DMA data proved to be an adequate source of elevation information for the purposes of this project. Data orientation, that being the actual spatial placement of the correct elevations on the map was quite accurate. We did find, however, that because of the truncation problems we discussed earlier, the extreme high and low elevations in the landscape tended to disappear. The high and low elevation checks we built into our assignment of elevation classes were in fact never violated. Instead, the elevation class for the River often disappeared, as did the #9 class containing the highest elevations. This made it all the more necessary to actually draw the River onto the elevation maps to provide for our basic orientation.

This tendency to raise the River and lower the ridges implies that the mapped viewshed may be somewhat larger than the viewshed which actually exists. We did not consider this problem critical for the project. We feel that in this region, and for this resource, the exclusion of visible areas from the viewshed is a more serious problem than the inclusion of a slight area of nonvisible cells. The generalized 40 acre grid used for final legal boundary definition also negates this problem.

When reviewing the final VIEWIT maps, we found that the viewshed in several flatter areas appeared to be less accurate than the viewsheds for the steep areas. It appears that caution should be used when DMA data is applied for flatter, undulating landscapes. Both truncation and error margins have a much more pronounced affect in these landscapes. A test of accuracy should be made to ensure the effective use of DMA data for these areas.

In conclusion then, the steep terrain of the Missouri River landscape served as an optimal use situation, that being one in which the effects of both truncation and specified vertical and horizontal error margins are reduced. This advantage, along with the relative ease of operation and economic advantages made the DMA source a good alternative for this project.

Within the actual operations, the final elevation maps tended to be hard to read. Along with losing our high and low elevations, the numeric printout of these maps was hard to read from short distances. Distinctions between the numbers for different elevation classes were difficult to discern.

This problem can be reduced by placing gaps of elevations between the different classes. For example, the intervals 1350-1550, 1551-1750 might instead read 1350-1500, 1550-1700 and so on. This leaves a 50 foot elevation gap between classes. This gap shows up as a white band between the groups of numbers for each class. The maps with these bands would be much easier to read and comprehend.

In producing the final viewshed maps, the methodology for viewpoint selection proved to be successful. When we compared the VIEWIT viewsheds with the USGS quads and the eye/hand boundary maps, there was a general correlation and verification of information. In hindsight, when we reviewed the final width of the viewshed, we saw that the minimum radius of three miles was often larger than it really needed to be. Experience and closer reviews of viewpoint location and radius should help eliminate most of these unnecessary actions.

In mapping the final scenic rim-to-rim boundaries, the user should keep in mind the error margins we discussed earlier. The outer edge of the viewshed delineates a boundary "zone," rather than a distinct line. This zone must be kept in mind when the final 40 acre legal boundary is mapped. Field checks should be made to verify any questionable situations.

In order to create the visual vulnerability maps, uniform distances must be maintained between viewpoints in the final VIEWIT run. If they are placed in too random a fashion, relating areas on a single map or in a series becomes relative and meaningless. For instance, if we have two somewhat similar areas, and use six viewpoints to scan the first and ten to scan the second, the number of times seen in each area will point to a difference that does not exist. This complicates production and reduces the reliability and relatability within and between the final project maps.

Finally, our system of overlapping maps was not possible in certain instances due to the DMA data file characteristics we discussed earlier. Our information at these lines of map juxtaposition is not as exact, calling for some interpolation of detail. Management and siting activities must be more carefully checked in these areas to ensure accurate decisions.

This was the first time the BLM used VIEWIT or any other computer program to study a Wild and Scenic River. Its use verified the scenic boundaries produced initially by the manual process. We found locations of possible boundary error, these being the areas which are closely field checked. The actual total viewshed area will not change to a great extent. Total increase should be roughly equivalent to total decrease, resulting in a tighter boundary, not a major shift in total viewshed acreage. Thus, a more accurate scenic boundary can be determined, supported with mapped documentation.

The far reaching implications of the viewshed and system data show the advantage of using a computer system such as VIEWIT. Its potential goes beyond strictly delineating viewsheds and scenic boundaries, being able to perform also as a planning/management tool.

This was the first time that actual graduations of visual vulnerability within the scenic boundaries were mapped. Also, a quantitative measure was assigned to the viewpoints along the River since the total acreage of seen areas is recorded for each separate viewpoint.

Finally, with its potential for checking the visual impacts of any proposed activities within the viewshed, and producing slope data quickly and at a reasonable cost, the advantage of a computer system such as VIEWIT over manual mapping processes is quite pronounced. Such a computer system can perform as a viable tool, constantly useful in providing the information on which to base management and planning decisions, and in aiding the review of those decisions prior to implementation.

Overall, we feel this project was very successful, and can be used in an ongoing role as one of the many factors which will help us to maintain this great natural resource, the Upper Missouri Wild and Scenic River.

```
VV        VV         IIIIII         EEEEEEEEEEEE      WW        WW
VV        VV         IIIIII         EEEEEEEEEEEE      WW        WW
 VV      VV            II           EE                WW        WW
 VV      VV            II           EE                WW        WW
  VV    VV             II           EE                WW        WW
  VV    VV             II           EEEEEEEE          WW   WW   WW
   VV  VV              II           EEEEEEEE          WW  WWWW  WW
   VV  VV              II           EE                WW WWWWWW WW
    VVVV               II           EE                WWWWW  WWWWW
    VVVV               II           EE                WWWW    WWWW
     VV              IIIIII         EEEEEEEEEEEE      WWW      WWW
     VV              IIIIII         EEEEEEEEEEEE      WW        WW
```

DMA TAPE TRANSLATION

5 Files

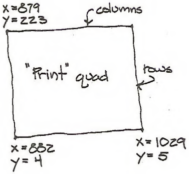
```
21:>LNP!
      1:@ASG,TJ DMA*IN.,U9V//////Q,UR6432
      2:@USE 7.,DMA*IN.
      3:@REWIND 7.
      4:@MOVE 7.,1
      5:@ASG,T GEOM*L1202E.,U9V
      6:@USE 8.,GEOM*L1202E.       GREAT FALLS EAST
      7:@ASG,A DTIS*ABS.
      8:@XQT DTIS*ABS.COPYNCIC
      9:@FREE,S 8.
     10:@REWIND 7.
     11:@MOVE 7.,4
     12:@ASG,T GEOM*L1203E.,U9V  LEWISTOWN EAST
     13:@USE 8.,GEOM*L1203E.
     14:@XQT DTIS*ABS.GOPYNCIG
     15:@FREE,S 8.
     16:@REWIND 7.
     17:@MOVE 7.,7
     18:@ASG,T GEOM*M1212W.,U9V  HAVRE WEST
     19:@USE 8.,GEOM*M1212W.
     20:@XQT DTIS*ABS.COPYNGIC
     21:@FREE,S 8.
     22:@REWIND 7.
     23:@MOVE 7.,10
     24:@ASG,T GEOM*L1301W.,U9V  JORDAN WEST
     25:@USE 8.,GEOM*L1301W.
     26:@XQT DTIS*ABS.COPYNGIC
     27:@FREE,S 8.
     28:@REWIND 7.
     29:@MOVE 7.,13
     30:@ASG,T GEOM*L1203W.,U9V  LEWISTOWN WEST
     31:@USE 8.,GEOM*L1203W.
     32:@XQT DTIS*ABS.GOPYNGIC
     33:@FREE,S 8.
     34:@EOF
EOF:34
0:>EXIT
LINES:34 FIELDATA
>@FIN
```

PRINT OUTPUT

```
LEWISTOWN                          WEST

 THE AMS 1/250,000 SHEET NL-12-3       IS ON TAPE F00626      .
 THE S.W. COORDINATES FOR THIS HALF ARE LATITUDE =     47-00 AND LONGITUDE =    110-00.

IXSW =  203    IYSW =    124

X=    23   X=   169   X=   316   X=   463   X=   610   X=   756   X=   903   X=  1050   X=  1197
Y=  1751   Y=  1749   Y=  1748   Y=  1747   Y=  1746   Y=  1745   Y=  1745   Y=  1744   Y=  1744

X=    20   X=   166   X=   313   X=   461   X=   608   X=   754   X=   902   X=  1049   X=  1197
Y=  1532   Y=  1530   Y=  1529   Y=  1528   Y=  1527   Y=  1526   Y=  1526   Y=  1525   Y=  1525
DARK BUTTE  ILIAD   PIGTAIL    CHASE HILL  KAGI AND  LEROY     BIRD RAPIDS STURGEON
                     COULEE                  BENCH                           ISLAND

X=    17   X=   164   X=   311   X=   459   X=   607   X=   753   X=   901   X=  1049   X=  1197
Y=  1313   Y=  1311   Y=  1310   Y=  1309   Y=  1308   Y=  1307   Y=  1307   Y=  1306   Y=  1306
LAST CHANCE STARVE OUT PN RANCH COUNCIL    GALLATIN   TAFFY        X          X
  BENCH        FLAT               ISLAND     RAPIDS      RIDGE
7          8          9          10         11         12         13         14
X=    14   X=   161   X=   309   X=   457   X=   605   X=   752   X=   900   X=  1048   X=  1197
Y=  1094   Y=  1092   Y=  1091   Y=  1090   Y=  1089   Y=  1089   Y=  1088   Y=  1087   Y=  1087
           [illegible] WOLF      ANDERSON
             COULEE    CREEK      BRIDGE
                         FALLS

X=    11   X=   159   X=   307   X=   455   X=   604   X=   751   X=   900   X=  1048   X=  1197
Y=   875   Y=   874   Y=   873   Y=   872   Y=   871   Y=   870   Y=   870   Y=   869   Y=   868

X=     8   X=   156   X=   305   X=   453   X=   602   X=   750   X=   899   X=  1048   X=  1197
Y=   656   Y=   655   Y=   654   Y=   653   Y=   652   Y=   651   Y=   651   Y=   650   Y=   649

X=     5   X=   154   X=   303   X=   451   X=   601   X=   749   X=   898   X=  1047   X=  1197
Y=   437   Y=   436   Y=   435   Y=   434   Y=   433   Y=   433   Y=   432   Y=   431   Y=   430

X=     2   X=   151   X=   301   X=   449   X=   599   X=   748   X=   897   X=  1047   X=  1197
Y=   218   Y=   217   Y=   216   Y=   215   Y=   214   Y=   214   Y=   213   Y=   212   Y=   211

X=     0   X=   149   X=   299   X=   448   X=   598   X=   747   X=   897   X=  1047   X=  1197
Y=     0   Y=    -1   Y=    -2   Y=    -3   Y=    -4   Y=    -4   Y=    -5   Y=    -6   Y=    -7
```

USING "PRINT" DATA

Rows : 62.5 x ΔY
Columns : 52.08 x Δx



For figuring the numbers of rows and columns to specify in the VIEWIT Runstream.

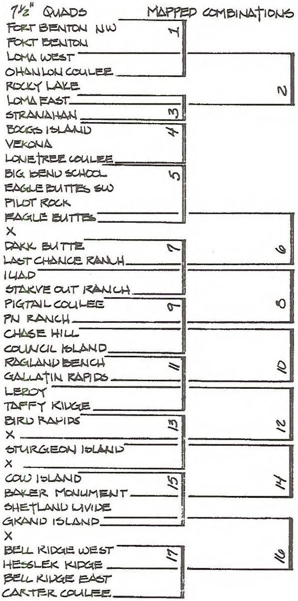
A: $\Delta y = 2.23'' - .04'' = \underline{2.19''}$ for rows
B: $\Delta x = 10.29'' - 8.82'' = \underline{1.47''}$ for columns

Rows: 62.5" x 2.19" = 137 rows
Columns: 52.08 x 1.47" = 77 columns

Elevation Map w/ Class Table

```
MAP OF ELEVATIONS BY USER-SPECIFIED CLASSES.

CLASS    LOWER LIMIT     UPPER LIMIT
-----    -----------     -----------
  1        2470.00         2530.00
  2        2531.00         2599.00
  3        2600.00         2699.00
  4        2700.00         2799.00
  5        2800.00         2899.00
  6        2900.00         2999.00
  7        3000.00         3099.00
  8        3100.00         3199.00
  9        3200.00         3299.00
 10            .00         2469.00
```

COMPOSIT MAPS showing over-lap system


7½" QUADS
MAPPED COMBINATIONS
FORT BENTON NW
FORT BENTON
LOMA WEST
OHANLON COULEE
ROCKY LAKE
LOMA EAST
STRANAHAN
BOGGS ISLAND
VEKONA
LONETREE COULEE
BIG BEND SCHOOL
EAGLE BUTTES SW
PILOT ROCK
EAGLE BUTTES
X
DARK BUTTE
LAST CHANCE RANCH
ILIAD
STARVE OUT RANCH
PIGTAIL COULEE
PN RANCH
CHASE HILL
COUNCIL ISLAND
RAGLAND BENCH
GALLATIN RAPIDS
LEROY
TAFFY RIDGE
BIRD RAPIDS
X
STURGEON ISLAND
X
COW ISLAND
BAKER MONUMENT
SHETLAND DIVIDE
GRAND ISLAND
X
BELL RIDGE WEST
HESSLER RIDGE
BELL RIDGE EAST
CARTER COULEE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

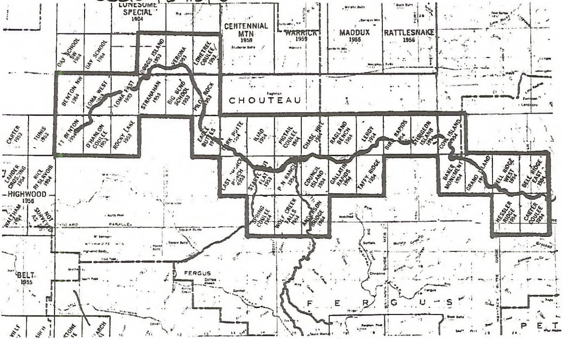
ELEV

ELEVATION DATA

MAP	HIGH	LOW	DIFF.
1	3520	2550	960
2	3520	2550	960
3	3060	2520	540
4	3280	2480	800
5	3540	2440	1100
6	3540	2440	1100
7	3560	2420	1140
8	3560	2400	1160
9	3440	2380	960
10	3460	2360	1090
11	3520	2340	1180
12	3320	2320	1200
13	3320	2280	1040
14	3300	2260	1040
15	3200	2260	1460
16	2280	2240	960
17	3200	2220	980

HIGH 3720'
LOW 2220'
RIVER DROP 330'

USGS 7½" maps


LONESOME SPECIAL 1904
CENTENNIAL MTN 1959
WARRICK 1959
MADDUX 1956
RATTLESNAKE 1956
DAY SCHOOL SW 1964
DAY SCHOOL 1964
BOGGS ISLAND 1953
VERONA 1953
LONETREE COULEE 1953
BENTON NW 1964
LOMA WEST 1953
LOMA EAST 1953
STRANAHAN 1953
BIG BEND SCHOOL 1953
PILOT ROCK 1953
CHOUTEAU
CARTER 1953
TUNIS 1953
FT. BENTON 1954
O'HANLON COULEE 1953
ROCKY LAKE
EAGLE BUTTES
DARK BUTTE 1954
ILIAD 1954
PIGTAIL COULEE 1964
CHASE HILL
RAGLAND BENCH 1964
LEROY 1964
BIRCH RAPIDS 1954
STURGEON ISLAND 1954
COW ISLAND 1954
LAST CHANCE RANCH 1953
STAFFORD FLAT 1953
P N RANCH 1954
COUNCIL ISLAND
GALLATIN RAPIDS 1954
TAFFY RIDGE 1954
BAKER MONUMENT 1954
GRAND ISLAND
BELL RIDGE WEST 1954
BELL RIDGE EAST 1954
LANDER CROSSING
RICE RESERVOIR
HIGHWOOD 1956
WALTHAM 1954
NOT SURVEYED AS 7½
SPRING COULEE 1964
WOLF CREEK FALLS 1954
ANDERSON BRIDGE 1954
HESSLER RIDGE 1954
CARTER COULEE 1954
BELT 1955
FERGUS
F E R G U S
P E T

Composit maps	OBS.	MAX.OBS.	#cells high
MAP ONE	22	18	(1)
MAP TWO	35	17	(1)
MAP THREE	26	23	(1)
MAP FOUR	35	21	(5)
MAP FIVE	52		
MAP SEVEN	38		
MAP EIGHT	20	17	(4)
MAP NINE	14	14	(30)
MAP TEN	20	17	(1)
MAP ELEVEN	18	17	(1)
MAP TWELVE	24	16	(2)
MAP THIRTEEN	27	18	(2)
MAP FOURTEEN			
MAP FIFTEEN	42	21	(1)
MAP SIXTEEN	25	16	(2)
MAP SEVENTEEN	27	21	(1)

VIEWIT BATCH RUNSTREAM

```
LNP!
      1:@ASG,A ELEV*ONEM.
      2:@USE ZDATA.,ELEV*ONEM.
      3:@ASG,A PSW*VIEWIT.
      4:@XQT PSW*VIEWIT.
      5:BY COLS,COL UP,NROWS=275,NCOLS=155,FORMAT=´(16F5.0)´,READ,
      6:CLEAR,RADIUS=3.0,ZBIAS=6,SHOWNZ,
      7:OBS=(60,80),VIEW,OBS=(64,82),VIEW,OBS=(68,86),VIEW,
      8:OBS=(79,97),VIEW,OBS=(84,103),VIEW,OBS=(93,102),VIEW,
      9:OBS=(96,102),VIEW,OBS=(101,102),VIEW,OBS=(103,106),VIEW,
     10:OBS=(99,119),VIEW,OBS=(98,126),VIEW,OBS=(105,136),VIEW,
     11:OBS=(114,130),VIEW,OBS=(117,127),VIEW,
     12:RADIUS=6.0,
     13:OBS=(56,78),VIEW,OBS=(77,94),VIEW,OBS=(74,88),VIEW,
     14:OBS=(109,112),VIEW,OBS=(105,116),VIEW,OBS=(97,138),VIEW,
     15:OBS=(102,138),VIEW,OBS=(53,74),VIEW,
     16:MTITLE=´ELEV*ONEM´,
     17:TABLE,AVG MAP,GMAP,
```

VIEWIT
MAP ONE

```
     18:@ASG,A ELEV*MTWO.
     19:@USE ZDATA.,ELEV*MTWO.
     20:@XQT PSW*VIEWIT.
     21:BY COLS,COL UP,NROWS=275,NCOLS=154,FORMAT=´(16F5.0)´,READ,
     22:CLEAR,RADIUS=3.0,ZBIAS=6,SHOW NZ,
     23:OBS=(44,124),VIEW,OBS=(48,121),VIEW,OBS=(51,119),VIEW,
     24:OBS=(57,118),VIEW,OBS=(64,115),VIEW,OBS=(68,115),VIEW,
     25:OBS=(77,131),VIEW,OBS=(79,143),VIEW,OBS=(82,142),VIEW,
     26:OBS=(87,141),VIEW,OBS=(90,142),VIEW,OBS=(95,145),VIEW,
     27:OBS=(99,148),VIEW,OBS=(102,155),VIEW,OBS=(89,174),VIEW,
     28:OBS=(104,164),VIEW,OBS=(104,168),VIEW,OBS=(99,178),VIEW,
     29:OBS=(79,183),VIEW,
     30:RADIUS=4.0,
     31:OBS=(95,196),VIEW,OBS=(94,202),VIEW,OBS=(99,209),VIEW,
     32:OBS=(103,212),VIEW,OBS=(105,212),VIEW,
     33:RADIUS=6.0,
     34:OBS=(73,118),VIEW,OBS=(76,122),VIEW,OBS=(75,139),VIEW,
     35:OBS=(104,159),VIEW,OBS=(104,174),VIEW,OBS=(84,177),VIEW,
     36:OBS=(84,192),VIEW,OBS=(77,196),VIEW,OBS=(86,198),VIEW,
     37:OBS=(101,211),VIEW,OBS=(111,211),VIEW,
     38:MTITLE=´ELEV*MTWO´,
     39:TABLE,AVG MAP,GMAP,
```

MAP TWO

```
     40:@ASG,A ELEV*MTHREE.
     41:@USE ZDATA.,ELEV*MTHREE.
     42:@XQT PSW*VIEWIT.
     43:BY COLS,COL UP,NROWS=138,NCOLS=154,FORMAT=´(16F5.0)´,READ,
     44:CLEAR,RADIUS=3.0,ZBIAS=6,SHOW NZ,
     45:OBS=(69,82),VIEW,OBS=(73,80),VIEW,OBS=(77,85),VIEW,
     46:OBS=(79,92),VIEW,OBS=(79,96),VIEW,OBS=(79,103),VIEW,
     47:OBS=(80,88),VIEW,OBS=(82,107),VIEW,OBS=(84,116),VIEW,
     48:OBS=(88,120),VIEW,OBS=(112,122),VIEW,OBS=(117,125),VIEW,
     49:OBS=(96,128),VIEW,OBS=(101,126),VIEW,OBS=(106,123),VIEW,
     50:OBS=(116,137),VIEW,
     51:RADIUS=4.0,
     52:OBS=(41,73),VIEW,OBS=(45,77),VIEW,OBS=(47,81),VIEW,
     53:OBS=(47,84),VIEW,OBS=(49,88),VIEW,OBS=(56,92),VIEW,
     54:OBS=(63,84),VIEW,
     55:RADIUS=6.0,
     56:OBS=(49,92),VIEW,OBS=(85,111),VIEW,OBS=(93,127),VIEW,
     57:MTITLE=´ELEV*MTHREE´,
     58:TABLE,AVG MAP,GMAP,STOP,
EOF:58
0:>EXIT
LINES:58 FIELDATA
```

MAP THREE

Bureau of Land Management
Library
Bldg. 50, Denver Federal Center
Denver, CO 80225

VIEWIT MAP
STATISTICS TABLE

```
TABLE OF NUMBERS OF CELLS AND AREAS SEEN BY      27 OBSERVER(S).

          TIMES SEEN           CELLS          AREA:  SQUARE MILES          ACRES       HECTARES
==================================================================================================
               0               36763                       175.83      112528.26       45538.75
               1                1366                         6.53        4181.20        1692.08
               2                 730                         3.49        2234.46         904.26
               3                 429                         2.05        1313.13         531.41
               4                 388                         1.86        1187.63         480.62
               5                 431                         2.06        1319.25         533.88
               6                 382                         1.83        1169.27         473.19
               7                 450                         2.15        1377.41         557.42
               8                 390                         1.87        1193.76         483.10
               9                 253                         1.21         774.41         313.39
              10                 302                         1.44         924.40         374.09
              11                 197                          .94         603.00         244.03
              12                 244                         1.17         746.86         302.25
              13                  53                          .25         162.23          65.65
              14                  44                          .21         134.68          54.50
              15                  26                          .12          79.58          32.21
              16                  18                          .09          55.10          22.30
              17                   1                          .00           3.06           1.24
              19                   2                          .01           6.12           2.48
              21                   1                          .00           3.06           1.24
==================================================================================================
```